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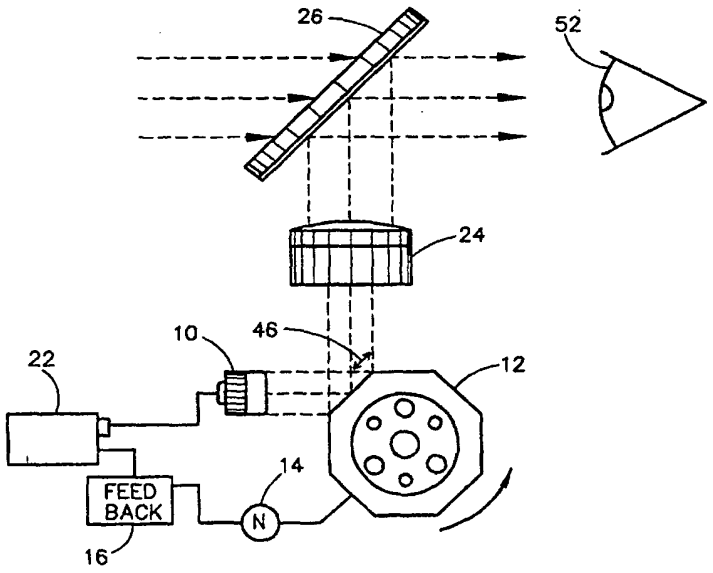

(57) Abstract

A personal display apparatus and method is disclosed which provides a visual image combined with background scene. The display image is created by a linear array of light emitting diodes (LEDs). A two-dimensional pattern is generated by reflecting the light off of a rotating mirror. The display pattern is reflected again into the user's eye, superimposing the backgroung scene and display image. A symbol generator controls the rotation of the mirror and the operation of the LEDs. The display system targets military vehicle and aircraft applications, but has many commercial applications.

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DAY/NIGHT HEADS-UP DISPLAY (HUD)

BACKGROUND OF THE INVENTION

Field of the Invention (Technical Field)

The invention relates to visual display, and more particularly to a heads-up display apparatus and method for projecting a display of flight or weapons information to a pilot.

Background Art

Since man has flown aircraft, there has been a continual search to keep a pilot informed as to flight display information in addition to keeping his eyes on the flight path. In the early years, these two requirements were diametrically opposing. In recent times, head mounted displays and displays superimposed upon objects in the pilot's line of sight have proliferated.

Many of the display systems use cathode-ray tube (CRT) construction attached to a helmet, or mirrored to a screen or similar device, for heads-up viewing by a pilot. Other known devices teach the use of fiber optic cables for carrying CRT images to a similar viewing device. However, CRT devices have many drawbacks, such as their weight and bulk. Additionally, CRT systems are very expensive. Some of these prior art systems are described below.

U.S. Patent No. Re. 28,847 to Vizenor refers to a light emitting source, but describes no other source than a low light level television (TV) system which is a CRT device. The disclosed device is for superimposing an image on a helmet or helmet mounted device. There is no disclosure of a means for creating a display.

U.S. Patent No. 3,945,716 to Kinder teaches a CRT display apparatus and a fiber optic cable for transmission of an image onto a holographic lens. The device is affixed on a pivoting arm above a pilot's head.

U.S. Patent No. 3,940,204 to Withrington describes another CRT system in conjunction with a holographic lens.

U.S. Patent No. 4,269,476 to Gauthier et al., discloses a helmet mounted display system utilizing a CRT and a spherical mirror.

U.S. Patent No. 3,833,300 to Rymes describes an aiming system for projectiles using a CRT, fiber optic bundles and a visor in the form of two parabolas.

Some prior art devices use driven light emitting diodes (LEDs) to generate a two-dimensional display. The display system developed under U.S. Patent No. 4,311,999 to Upton et al., uses a clamped cantilevered array of vibrating fiber optic filaments to create the two-dimensional display. The array of fiber optic filaments is prone to fracture and has limitations to image quality and resolution.

U.S. Patent No. 3,958,235 to Duffy discloses a system similar to Upton et al., except reeds are used instead of fiber optic cables.

The device developed by Private Eye™ uses a flat vibrating mirror to create the display. The display image is not see-through and the image generator obstructs the user's eyesight.

SUMMARY OF THE INVENTION

In accordance with the present invention, there is disclosed a raster-type display apparatus and method whereby an image is created by a plurality of light sources energized in cooperation with a rotating mirror. The preferred apparatus for displaying an image comprises a plurality of light sources, a rotating mirror for receiving light from the light sources and reflecting the light, a symbol generator for synchronously energizing the light sources, a feedback structure for monitoring a rotation state of the rotating mirror and reporting the rotation state to a control of the symbol generator, and structure for projecting the reflected light from the rotating mirror onto a surface.

The preferred plurality of light sources comprises light emitting diodes.

The preferred rotating mirror comprises a polygon. An alternative polygon rotating mirror comprises angled facets. The rotating mirror can also comprise a multifaceted sphere.

The preferred feedback structure comprises a light emitter and light detector. An alternative feedback structure comprises electro-magnetic feedback from a motor for rotating the rotating mirror.

The preferred symbol generator comprises structure for controlling a speed of rotation of the rotating mirror.

The preferred structure for projecting the reflected light comprises a collimating lens.

The preferred surface comprises a surface that displays the reflected light and also allows ambient light to pass through. The preferred surface comprises a combiner element.

The preferred method for displaying an image comprises the steps of providing a plurality of light sources, providing a mirror for receiving light from the light sources and reflecting the light, rotating the mirror, synchronously energizing the light sources from a symbol generator, monitoring a rotation state of the rotating mirror and reporting the rotation state to a control of the symbol generator, and projecting the reflected light from the rotating mirror onto a surface.

The preferred step of providing a plurality of light sources comprises providing light emitting diodes.

The preferred step of providing a mirror comprises providing a polygon. The step of providing a mirror alternatively comprises providing angled facets. The step of providing a mirror can also comprise providing a multifaceted sphere.

The preferred step of monitoring a rotation state of the rotating mirror and reporting the rotation state to a control of the symbol generator comprises providing a light emitter and light detector. The step of monitoring a rotation state of the rotating mirror and reporting the rotation state to a control of the symbol generator alternatively comprises measuring electro-magnetic signals from a motor for rotating the mirror.

The preferred method further comprises the step of controlling a speed of rotation of the rotating mirror by the symbol generator.

The preferred step of projecting the reflected light comprises collimating the light through a lens. The step of projecting the reflected light also comprises displaying the reflected light on a surface and allowing ambient light to pass through. The preferred surface for displaying comprises a combiner element.

Also disclosed is an apparatus for displaying an image comprising structure for mounting a combiner element in the field of view of an observer, a plurality of light sources in a linear array, a rotating mirror for receiving light from the light sources and reflecting the light at predetermined angles of reflection, a symbol generator for synchronously energizing the light sources, a feedback structure for monitoring a rotation state of the rotating mirror and reporting the rotation state to a control of the

symbol generator, and structure for projecting the reflected light from the rotating mirror through a collimated lens and onto the combiner element.

The preferred structure for mounting a combiner element comprises affixing the combiner element to a helmet. The structure for mounting the combiner element comprises affixing the combiner element to night vision goggles.

Disclosed is an apparatus for displaying an image comprising a combiner element comprising a glass surface coated to enhance reflected light while allowing ambient light to pass through and mounting the combiner element on a helmet, 128 light emitting diodes in a linear array, a rotating polygon mirror for receiving light from the light emitting diodes and reflecting the light at predetermined angles of reflection, a symbol generator for synchronously energizing the light emitting diodes in a selected pattern, a feedback structure comprising a light emitter and light detector for monitoring a rotation state of the rotating polygon mirror and reporting the rotation state to a control of the symbol generator, and a collimating lens for projecting the reflected light from the rotating polygon mirror onto the combiner element.

A primary object of the present invention is to provide a visual display image in the line of sight combined with the background scene.

A primary advantage of the present invention is that it is significantly lighter in weight than CRT based systems.

Another advantage of the present invention is that it does not have a vibrating fiber optic cable that is subject to fracture as in other LED based systems.

Yet another advantage of the present invention is that it is significantly less expensive than CRT based systems.

Other objects, advantages and novel features, and further scope of applicability of the present invention will be set forth in part in the detailed description to follow, taken in conjunction with the accompanying drawings, and in part will become apparent to those skilled in the art upon examination of the following, or may be learned by practice of the invention. The objects and advantages of the invention may be realized and attained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated into and form a part of the specification, illustrate several embodiments of the present invention and, together with the description, serve to explain the principles of the invention. The drawings are only for the purpose of illustrating a preferred embodiment of the invention and are not to be construed as limiting the invention. In the drawings:

Fig. 1 schematically illustrates the preferred apparatus and method of the present invention;

Fig. 2 illustrates the preferred feedback apparatus;

Fig. 3 illustrates the preferred "see through" glass surface;

Fig. 4 shows a typical display generated by the invention;

Fig. 5 is a perspective view of an alternative embodiment of the rotating mirror;

Fig. 6 is another alternative embodiment of the rotating mirror; and

Fig. 7 shows the invention mounted on an aviator's helmet.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The heads-up display apparatus and method of the present invention comprise hardware components, providing to a pilot the ability to view information such as navigational data images or weapons data images within the immediate field of view of a pilot. In addition, the apparatus is "see through" so a pilot can see the display image in addition to the background scene.

The preferred display is mounted to the user's head, helmet or other structure in the pilot's line of sight. The preferred apparatus and method are depicted in Fig. 1. The dashed lines in Fig. 1 indicate light paths. The display image is created by an array of visible light sources such as a linear array of light emitting diodes (LEDs) **10**. The preferred LED array **10** is mounted to a substrate in a linear fashion. In the preferred embodiment, 128 LEDs are used for LED array **10**; however, different numbers of LEDs can be used, as well as different configurations.

Mirror **12** is mounted adjacent to the LED array **10** and is driven by a motor **14**, or other device well known in the art. The preferred mirror **12** is polygonal-shaped with each facet at a similar angle. The light from the LEDs is projected onto rotating mirror **12**, which is rotating such that the angle of reflection **46** of the light off of the mirror surfaces is continuously changing. The individual LEDs are strobed in a synchronous

fashion with respect to the mirror rotation such that a two-dimensional array of pixels is generated. The two-dimensional array of pixels is then collimated through collimating lens **24** and reflected on a glass surface **26** for the creation of a desired image.

The mirror rotation and LED strobe are controlled by display generator **22**, comprising a computer or other known symbol generators, which generates video images. The synchronization of rotating mirror **12** and the strobed LEDs is accomplished by a feedback mechanism **16**, such as a light emitter/detector. The mirror rotation and LED strobe are controlled by a symbol generator computer **22** which creates a video image. The LED light is reflected into the user's eye **52**. The reflecting surface **26** allows light to pass through or around such that the user is able to see beyond the reflecting image superimposed over the background scene as observed by the user. The display light is collimated through a lens **24** to create the appearance of coming from infinity.

The display quality is controlled by the revolutions per minute (RPM) of the motor that rotates polygon mirror **12** cooperatively with the strobing of the LEDs. The preferred RPM is approximately 600 RPM and the preferred strobe rate is approximately 80 Hz.

To coordinate mirror **12** rotation and the strobing of the individual LEDs, mirror **12** rotation is monitored and controlled by a feedback apparatus **16**. The preferred feedback apparatus as shown in Fig. 2, is a feedback LED emitter **18** that continuously emits a beam to mirror **12**. Light is reflected off mirror **12** onto a light detecting apparatus **20,** such as a transistor detector. As mirror **12** rotates, the angle of reflection of the light results in a pulsed signal from the transistor detector **20** and is fed back to symbol generator **22**. Symbol generator **22** counts the pulsed detector signal and synchronizes LED array **10** information with the rotation of mirror **12**.

Alternative feedback apparatuses **16**, such as mechanical counters or electro-magnetic feedback from the motor, could also be utilized in a similar fashion.

Individual LEDs from LED array **10** are strobed synchronously by symbol generator **22** that are well known in the art with modifications to accept the feedback signal from feedback apparatus **16**. The strobed light from the individual LEDs is reflected off mirror **12** and is collimated by collimating lens **24** and reflected off a glass surface **26** or the like. The preferred glass surface **26** as shown in Fig. 3 is a combiner

element **56** which is coated with a selectively reflective optical coating **54**. The use of such coatings is well known in the art. The preferred coating material **54** reflects light in the bandwidth of the LEDs to enhance the reflection of the display light while allowing ambient light to pass through. In this embodiment, the user can see the combined display symbology and the background scene.

Alternative embodiments for mirror **12** can also be utilized. The display size can be increased by changing the angle of every other facet of mirror **12** with respect to the drive shaft angle of the motor as shown in Fig. 5. Thus, the reflected light from the strobed LEDs **10,** off the angled facets, would create a larger display. The display size is proportional to the angle of the facets. As shown in Fig. 6, another alternative embodiment is for mirror **12** to comprise a spherical surface with multiple facets at predetermined angles to increase the display pattern for a fixed number of LEDs. In these alternative embodiments LED array **10** can consist of fewer individual LEDs. Additionally, different color LEDs can be positioned for reflection on certain facets for color displays.

Fig. 4 shows a typical display symbology **28** generated by the preferred embodiment as seen by the pilot.

Fig. 7 illustrates the preferred mounting position of a display unit **30** mounted to an aviator's helmet **32**. The display combiner element is positioned such that the display symbology is centered in the user's field of view **34**. The display **30** is fastened with an adjustment mechanism **36** to allow positioning for individual preference. The adjustment mechanism **36** can be a ball **40** and socket **42** mounted to an attachment arm **38**. The ball **40** is allowed to pivot in the socket **42** until alignment is obtained and then secured with a set screw or the like. The attachment arm **38** can be flexible to allow final adjustment.

The display unit **30** can also be mounted to a night vision imaging system by directing the reflected symbology into the objective lens of the night vision system (not shown).

This invention has been described herein in considerable detail in order to comply with the Patent Statutes and to provide those skilled in the art with the information needed to apply the novel principles and to construct and use such specialized components as are required. However, it is to be understood that the

invention is not restricted to the particular embodiment that has been described and illustrated, but can be carried out by specifically different equipment and devices, and that various modifications, both as to the equipment details and operating procedures, can be accomplished without departing from the scope of the invention itself.

Variations and modifications of the present invention will be obvious to those skilled in the art and it is intended to cover in the appended claims all such modifications and equivalents. The entire disclosures of all references, applications, patents, and publications cited above, and of the corresponding application(s), are hereby incorporated by reference.

CLAIMS

The embodiments of the invention in which an exclusive property or right is claimed are defined as follows:

1. An apparatus for displaying an image, comprising:

a plurality of light sources;

rotating mirror means for receiving light from said light sources and reflecting said light;

symbol generator means for synchronously energizing said light sources;

feedback means for monitoring a rotation state of said rotating mirror means and reporting said rotation state to a control of said symbol generator means; and

means for projecting said reflected light from said rotating mirror means onto a surface.

2. The invention of claim 1 wherein said plurality of light sources comprises light emitting diodes.

3. The invention of claim 1 wherein said rotating mirror means comprises a polygon.

4. The invention of claim 3 wherein said rotating mirror comprises angled facets.

5. The invention of claim 1 wherein said rotating mirror means comprises a multifaceted sphere.

6. The invention of claim 1 wherein said feedback means comprises a light emitter and light detector means.

7. The invention of claim 1 wherein said feedback means comprises an electro-magnetic feedback means from a motor for rotating said rotating mirror means.

8. The invention of claim 1 wherein said symbol generator means comprises a means for controlling a speed of rotation of said rotating mirror means.

9. The invention of claim 1 wherein said means for projecting said reflected light comprises a collimating lens.

10. The invention of claim 1 wherein said surface comprises a surface that displays said reflected light and also allows ambient light to pass through.

11. The invention of claim 11 wherein said surface comprises a combiner element.

12. A method for displaying an image, the method comprising the steps of:

a) providing a plurality of light sources;

b) providing a mirror for receiving light from the light sources and reflecting the light;

c) rotating the mirror;

d) synchronously energizing the light sources from a symbol generator;

e) monitoring a rotation state of the rotating mirror and reporting the rotation state to a control of the symbol generator; and

f) projecting the reflected light from the rotating mirror onto a surface.

13. The method of claim 12 wherein the step of providing a plurality of light sources comprises providing light emitting diodes.

14. The method of claim 12 wherein the step of providing a mirror comprises providing a polygon.

15. The method of claim 14 wherein the step of providing a mirror comprises providing angled facets.

16. The method of claim 12 wherein the step of providing a mirror comprises providing a multifaceted sphere.

17. The method of claim 12 wherein the step of monitoring a rotation state of the rotating mirror and reporting the rotation state to a control of the symbol generator comprises providing a light emitter and light detector.

18. The method of claim 12 wherein the step of monitoring a rotation state of the rotating mirror and reporting the rotation state to a control of the symbol generator comprises measuring electro-magnetic signals from a motor for rotating the mirror.

19. The method of claim 12 further comprising the step of controlling a speed of rotation of the rotating mirror by the symbol generator.

20. The method of claim 12 wherein the step of projecting the reflected light comprises collimating the light through a lens.

21. The method of claim 12 wherein the step of projecting the reflected light comprises displaying the reflected light on a surface and allowing ambient light to pass through.

22. The method of claim 21 wherein the surface comprises a combiner element.

23. An apparatus for displaying an image, comprising:

means for mounting a combiner element in the field of view of an observer;

a plurality of light sources in a linear array;

rotating mirror means for receiving light from said light sources and reflecting said light at predetermined angles of reflection;

symbol generator means for synchronously energizing said light sources;

feedback means for monitoring a rotation state of said rotating mirror means and reporting said rotation state to a control of said symbol generator means; and

means for projecting said reflected light from said rotating mirror means through a collimated lens and onto said combiner element.

24. The invention of claim 23 wherein said means for mounting a combiner element comprises affixing said combiner element to a helmet.

25. The invention of claim 23 wherein said means for mounting said combiner element comprises affixing said combiner element to night vision goggles.

26. An apparatus for displaying an image, comprising:

a combiner element comprising a glass surface coated to enhance reflected light while allowing ambient light to pass through;

mounting said combiner element on a helmet;

128 light emitting diodes in a linear array;

a rotating polygon mirror for receiving light from said light emitting diodes and reflecting said light at predetermined angles of reflection;

a symbol generator for synchronously energizing said light emitting diodes in a selected pattern;

a feedback structure comprising a light emitter and light detector for monitoring a rotation state of said rotating polygon mirror and reporting said rotation state to a control of said symbol generator; and

a collimating lens for projecting said reflected light from said rotating polygon mirror onto said combiner element.

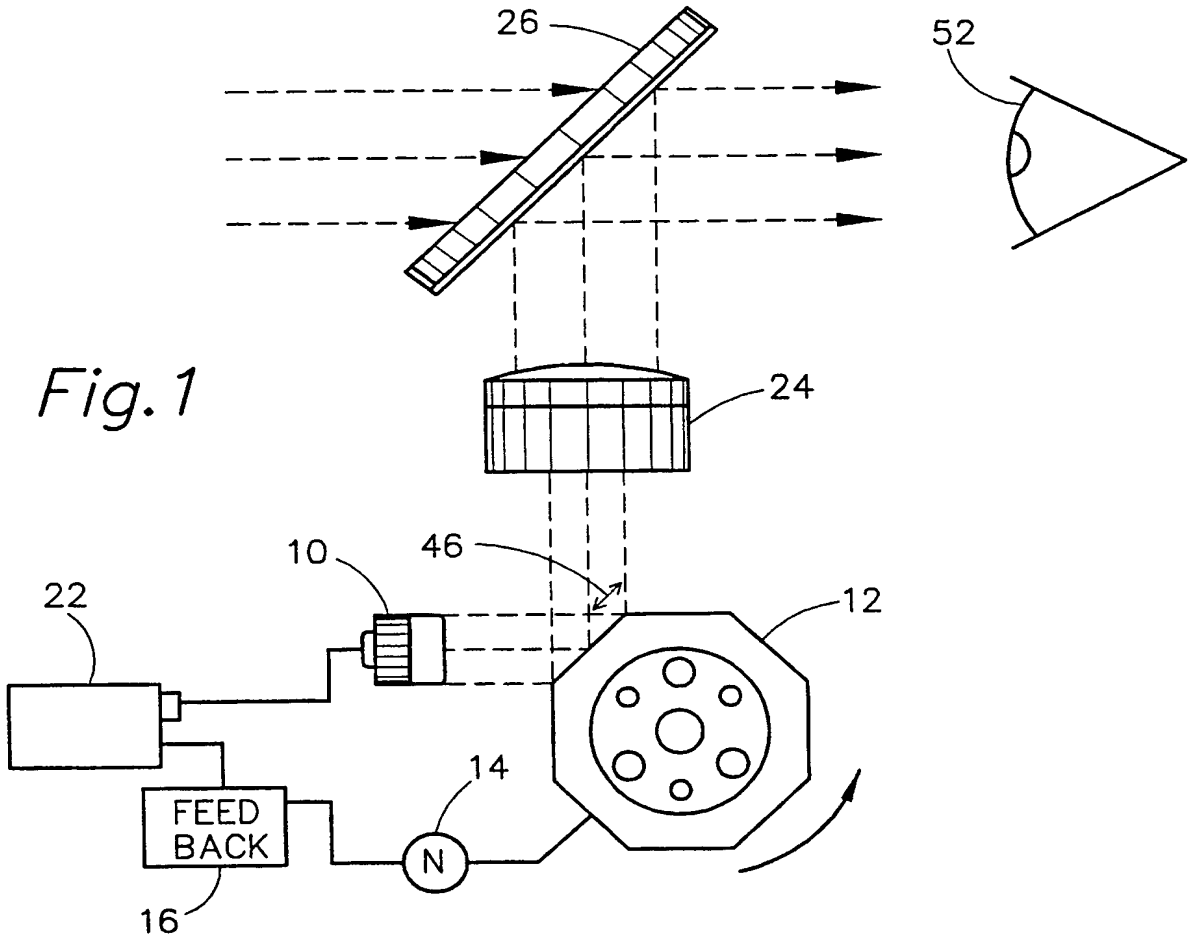

Fig. 1

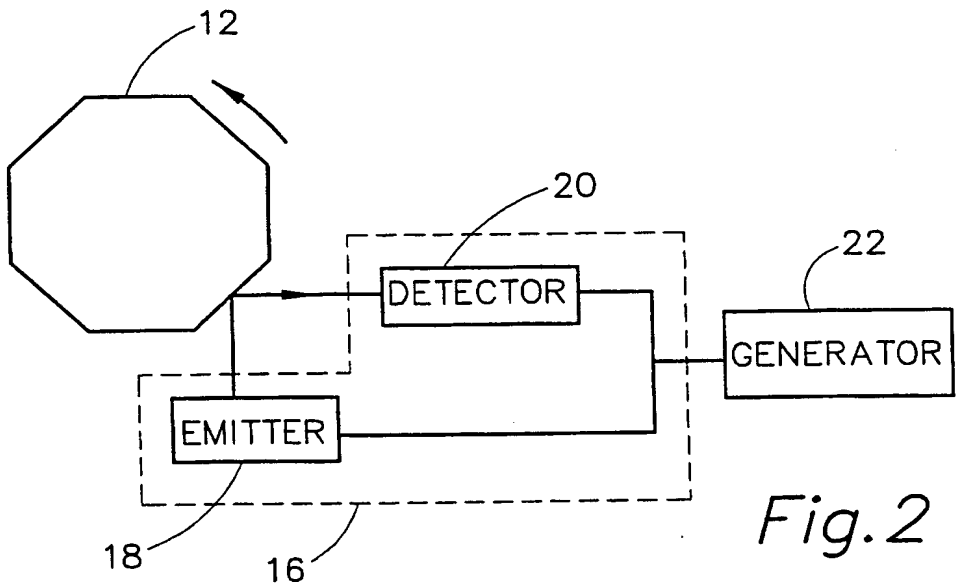

Fig. 2

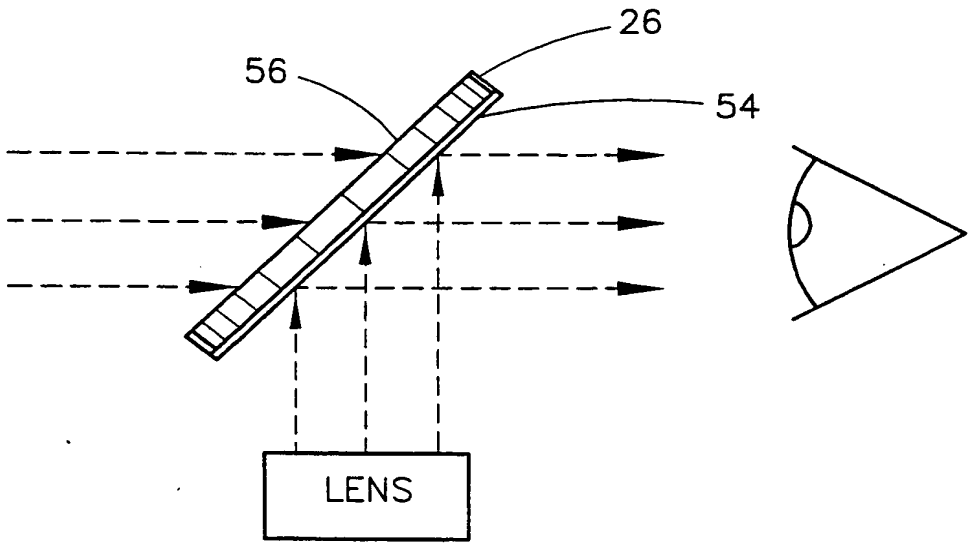

Fig. 3

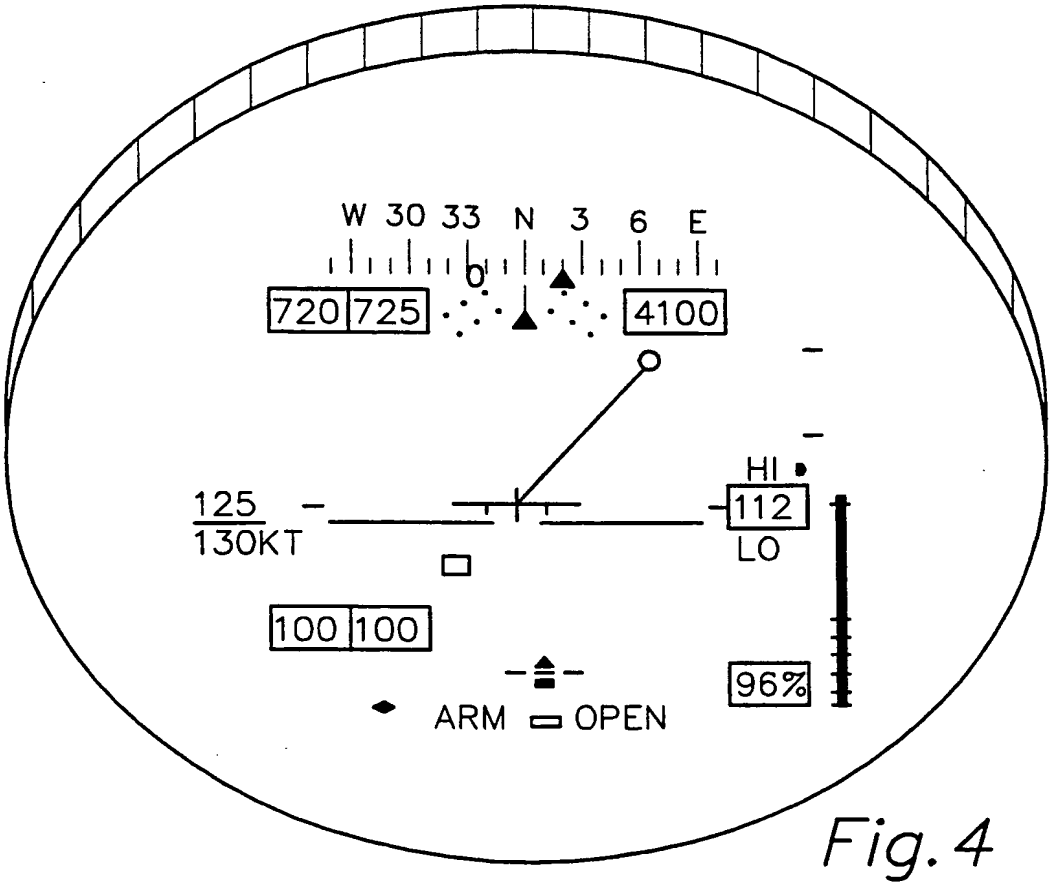

Fig. 4

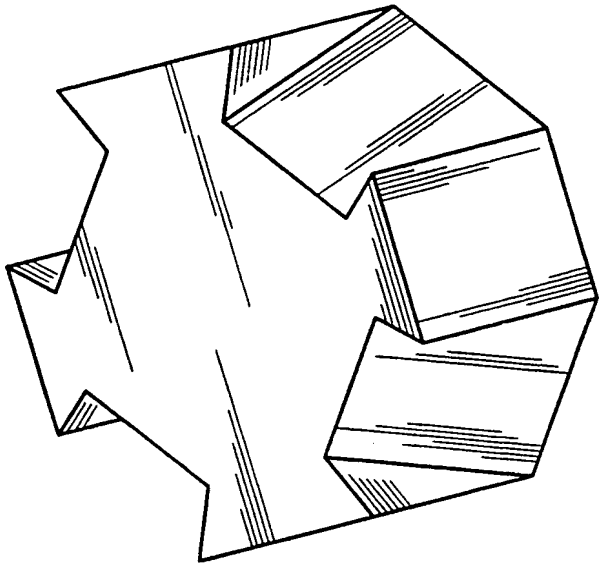

Fig. 5

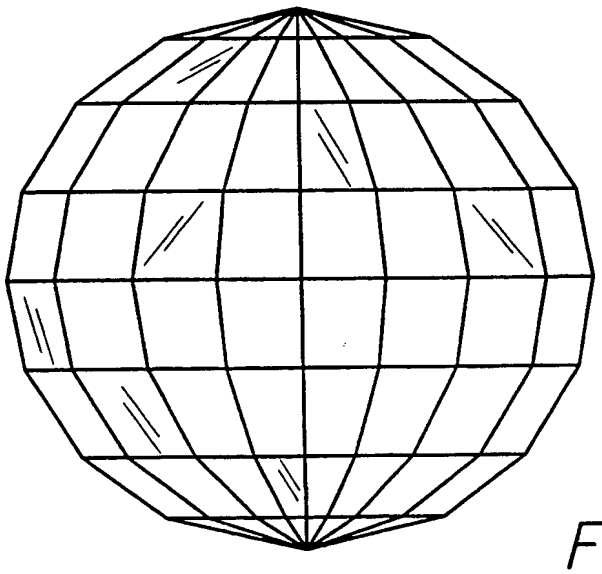

Fig. 6

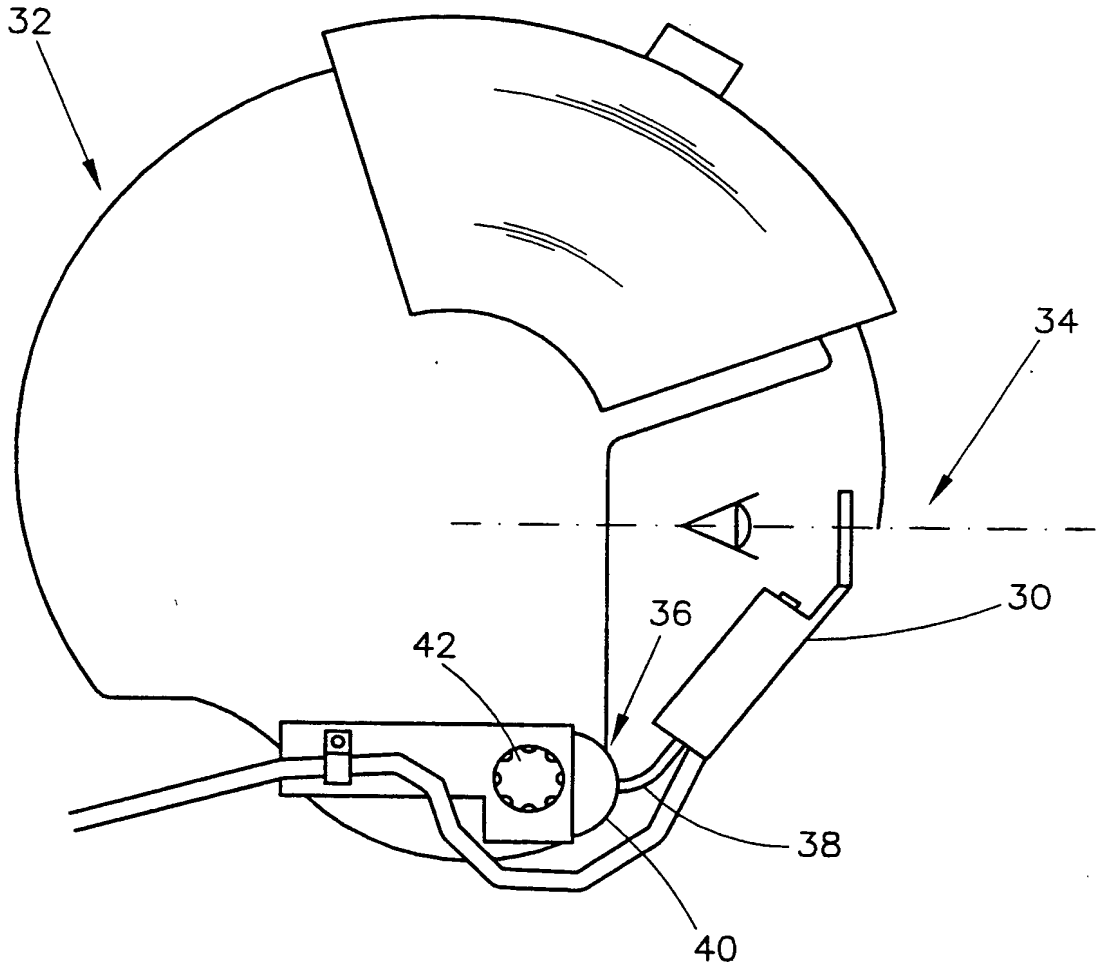

Fig. 7